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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM

OF THE

WASHINGTON MEETING

APRIL 24-25, 1925

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AMERICAN PHYSICAL SOCIETY

WASHINGTON MEETING, APRIL 24-25, 1925

The 133rd regular meeting of the American Physical Society will be held in Washington, D. C., at the Bureau of Standards on Friday and Saturday, April 24 and 25, 1925. The first session will be at 10 o'clock on Friday morning.

The Friday morning session and the Saturday afternoon session will be held in the Lecture Room of the East Building. On Friday afternoon and Saturday morning there will be sessions in both the Lecture Room of the East Building and the Lecture Room of the Industrial Building, Room 353, third floor. The schedule of papers is given in the calendar below.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction, they will be published in an early number of the Physical Review. Authors should send corrections to the Editor of the Physical Review at Corning, New York.

Dinner. On Friday evening there will be a dinner for members of the Society and their friends at the Raleigh Hotel at 6:30 P. M. The price per person will be $2.50. Tickets *must* be purchased before 2 o'clock, Friday afternoon.

CALENDAR

Friday morning at 10 o'clock.	East Building: Papers 1-12.
Friday afternoon at 2 o'clock.	East Building: Papers 13-23.
	Industrial Building: Papers 24-33.
Saturday morning at 10 o'clock.	East Building: Papers 34-44.
	Industrial Building: Papers 45-56.
Saturday afternoon at 2 o'clock.	East Building: Papers 57-66.

The supplementary papers beginning with No. 67 may be called for at the end of any one of the sessions held in the East Building.

Portland Meeting. The 134th regular meeting of the American Physical Society will be held in Portland, Oregon on June 19, 1925 in affiliation with the Pacific division of the A. A. A. S. Members intending to present papers at this meeting should have titles and abstracts (**not exceeding 211 words**) *ready for publication*, in the hands of the Local Secretary for the Pacific Coast, D. L. Webster, Stanford University, California, *not later than Saturday, May 16.*

Other meetings for the current seasons are as follows:

135. November 27-28, 1925. Chicago.

136. December 28-31, 1925. Kansas City. Annual Meeting.

HAROLD W. WEBB,
Secretary.

PROGRAM

FRIDAY MORNING AT 10 O'CLOCK

East Building

1. **X-radiation from crystalline antimony.** R. T. Cox, I. F. Zartman, and A. J. Allen, New York University.—A crystal of antimony used as the target of an x-ray tube gives off radiation of two kinds, diffuse and concentrated. The concentrated radiation produces on a film placed cylindrically around the tube a pattern of fine spots, arranged for the most part in lines. The pattern varies with the voltage applied to the tube. The diffuse and concentrated radiations differ in quality.

2. **New x-ray lines in certain rare earth samples.** C. J. Lapp and R. A. Rogers, State University of Iowa, and B. S. Hopkins, University of Illinois.—The Bureau of Standards' scientific paper No. 442 reports about 130 lines in the arc spectra of certain samples of neodymium and samarium that cannot be definitely assigned to any known element. The x-ray region from 1.240A to 2.800A has been carefully examined using the same samples mentioned above. The following lines have been found which cannot be assigned to any known elements: 1.6927, strong; 1.5878 very strong (almost as strong as Cu L α); 1.5486, fair; 1.4051, weak; 1.3753, weak; 1.3604, fair; 1.3441, weak; 1.2487, strong. These measurements were made using the copper and iron K series and the tungsten L series lines as reference lines. Work is now under way to photograph the K series of these samples.

3. **Soft x-rays from cobalt, nickel, and copper.** Charles H. Thomas, Princeton University.—The method for the photo-electric determination of critical radiating potentials as previously reported (Phys. Rev., **25**, 319, 1925) was used to find the critical radiating potentials of Ni, Co, and Cu. Between 0-1500 volts 47 critical potentials were found for Ni, 48 for Co, and a further study on iron brought the number to 45. These potentials show a shift upward with increasing atomic number. The agreement of the position of the breaks for Ni, Co, and Fe is especially good for the nine breaks which resemble ionization potentials. A study of part of the region 1-1500 volts for Cu gave the breaks of the L-series in agreement with the other metals but in the region 0-90 volts in which 21 breaks were found there is no regular agreement between the position of the breaks for Cu and those of the other metals for the corresponding region for which Ni shows 19 breaks. Potentials were found which correspond to the following L-series lines: for Fe, L_I at 818.5, L_{III} at 704.3; for Co, L_I at 873.2, L_{III} at 764.8; $Ni_I - L$ 948, L_{III} at 833.4; and for Cu, L_I at 1017 and L_{III} at 929 volts. These potentials agree well with predicted values. Five volts have been added to each potential to compensate for the "work function."

4. **Soft x-rays and secondary electrons.** F. L. Rose, Norman Bridge Laboratory of Physics.—Electrons of 200 v. velocity strike a target producing secondary electrons and soft x-rays. These are projected through a grid, to which a retarding potential is applied, against the radiator. The tertiary electrons produced are analyzed by means of slit, magnetic field, and photographic plate. This work, reported by Becker, has been continued and the main experimental results verified. The line reported at the 200 v.

limit has been checked with retarding potentials up to 200 v., but its disappearance when this potential is increased to 250 v. indicates that the interpretation that is due to homogeneous soft x-rays is in error, and we must fall back on double reflection of electrons without loss of energy. A continuous spectrum of soft x-rays has been proven to exist by the same plates. The voltage range has not yet been extended far enough to indicate the existence or absence of any anomalies.

5. X-ray radiation from hot sparks. ALBERT BJORKESON, Norman Bridge Laboratory of Physics.—The x-ray radiation from "hot sparks" has been analyzed with a vacuum-spectrograph of Siegbahn's type, using gypsum as crystal. The results show all the characteristic lines for the elements used as electrodes. Special experiments showed that to a very great extent these x-rays are radiated from the solid electrodes rather than from the vapors in the spark itself.

6. Refraction of x-rays by a prism of copper. BERGEN DAVIS and C. M. SLACK, Columbia University.—A measurement of the refraction of x-rays by a glass prism, using the photographic method, was recently reported by Larrson, Siegbahn and Waller (Phys. Rev., **25**, 235, 1925). The present experiments were made by means of an ionization spectrometer. The radiation was the copper $K\beta$ and $K\alpha$ lines. The angle of the copper prism was 63°. The results for the $K\alpha$ refraction agree fairly well with the Lorentz dispersion formula. The $K\beta$ frequency lies so near the copper absorption limit that the Lorentz unmodified formula leads to a negative value of δ. A positive value of δ, however, was found. The two positive values of δ for the $K\alpha$ and $K\beta$ lines were such as to indicate resonant absorption as the applied frequency approaches the critical frequency. The indications are that the branches of the dispersion curves are rounded off and do not approach infinity. The behavior is probably similar to the dispersion in the case of ordinary light near a critical resonance frequency.

7. On the index of refraction of x-rays and deviations from Bragg's law. F. C. BLAKE, Ohio State University.—At the Ann Arbor meeting of the American Physical Society it was shown that in order properly to correct for penetration into the sample in using the powder method of x-ray analysis there was needed but a single correction in case the rays were rendered monochromatic by filtering. This correction is a function of the depth of the effective plane with respect to the center of the sample and also of the glancing angle. When the penetration correction is applied all the reflecting planes of a crystal lead to the same space lattice and there is no discrepancy in Bragg's law for the different orders of reflection. If the penetration correction is not made and the apparent deviations in Bragg's law be interpreted as due to an index of refraction one is led to the absurdity that the sign of the deviation from unity for the index varies with the thickness of the sample. Various illustrations are given in support of these statements.

8. An application of certain quantum laws to the analysis of crystals. WILLIAM DUANE, Harvard University.—To explain diffraction phenomena the author proposed the theory that radiation momentum is transferred to the diffracting matter in quanta; and according to a further development of the idea by Epstein and Ehrenfest the intensity (probability) in a given direction is proportional to the square of the coefficient A of that term in the Fourier's Series, representing the density of the matter, which corresponds to the number of quanta transferred (Proc. Nat. Acad. Sci., May, 1923; April, 1924). If we reverse the line of thought and attempt to deduce the distribution of the diffracting matter (electrons in a crystal) from the measured intensities of reflections by adding together the corresponding Fourier terms, we find that these intensities

do not determine the phase angles δ. The symmetry of the crystal fixes the values of many, sometimes of all the δ's and often indicates that certain A's equal each other, but, in general, leaves the algebraic signs of the A's undetermined. Thus a large number of different distributions of matter conform to the same symmetry conditions and produce the same diffracted rays. Often other facts (position of origin, number of electrons near a point, etc.) will determine the signs.

9. The application of Fourier's series to crystal analysis. R. J. HAVIGHURST, National Research Fellow, Harvard University (introduced by William Duane).—This paper describes an application of the quantum theory (Duane, Proc. Nat. Acad. Sci. **9**, 159, 1923) and the correspondence principle (Epstein and Ehrenfest, Proc. Nat. Acad. Sci. **10**, 133, 1924) to the problem of electron distribution in crystals. The relative reflecting powers of the crystal planes of certain salts are obtained from x-ray measurements by the powdered crystal method. The square roots of these relative reflecting powers are used as coefficients in a Fourier's series (Epstein and Ehrenfest, loc. cit.). The distribution of electron density is obtained for different directions through the crystal, and comparisons are made between different salts of the same general structure.

10. The separation and relative intensity of the components of the Kβ line in the x-ray spectrum of molybdenum. SAMUEL K. ALLISON (National Research Fellow) and ALICE H. ARMSTRONG, Harvard University.—In 1920 M. de Broglie obtained photographic evidence of the doublet nature of the Kβ line in W and Rh and Duane and Patterson found evidence of a weaker component of the Kβ line in the Mo spectrum. Using a new precision ionization spectrometer, and slits limiting the angular width of the beam to about 2 minutes, we have obtained a separation of the components which is almost complete in the 5th order from calcite. An average of several determinations gives $\Delta\lambda = .000566 \pm .000014$ A or $\Delta\lambda/\lambda = .09$ percent. The doublet is a so-called "relativity" doublet, the transitions involved being $\beta_1 = K - M_{III}$, $\beta_3 = K - M_{II}$. The separation can therefore be calculated from the wave-lengths of the $L\beta_2$ and $L\beta_4$ lines of Mo. This gives $\Delta\lambda = .000564$ A. The relative intensity of the shorter wave-length component to the longer is 2 to 1 within experimental error. The relative intensities of the β_3 and β_1 lines are functions of the probabilities of the transitions $M_{II} - K$, $M_{III} - K$. The observed intensity ratio agrees with recent theoretical predictions.

11. The separation of Zr and Hf. DOROTHY HALL DROPHY and WHEELER P. DAVEY, General Electric Company.—Filters of zirconium compounds are widely used to screen out the beta and gamma lines of the Mo K spectrum. Their efficiency is lowered by the presence of impurities, especially those of higher atomic weight. A chemical method of purification of zirconium is therefore extremely important. It has been found by one of us that, contrary to what might have been expected from the literature, zirconium citrate is relatively insoluble in pure water, while hafnium citrate is quite soluble. Zirconium citrate is also soluble in ammonium hydroxide or in an excess of citric acid. By adding a limited amount of an aqueous solution of citric acid to a solution of crude zirconium nitrate, a precipitate of pure zirconium citrate is obtained which was identified by its x-ray absorption spectrum. X-ray absorption spectra of the water-soluble citrate showed the presence of hafnium. The conditions of the separation are such that although the precipitate is free from hafnium the soluble portion contains some zirconium.

12. Quantum theory of the intensity of the modified band in the Compton effect. G. E. M. JAUNCEY, Washington University.—The theory of a previous paper (Phys. Rev., **25**, 314, 1925) is extended to the scattering of x-rays by electrons in elliptic orbits,

in which case the intensity (energy per unit wave-length width) near the center of the modified band is much greater than near the edges of the band. The theory indicates that, when the band produced by scattering by a certain type (K, L, M) of electrons begins at a wave-length change $\lambda_0^2/(\lambda_s-\lambda_0)$, an unmodified line is also present. When all the electrons in an atom are operative in the scattering process the modified band is a composite of the modified bands due to each respective type of electron. The intensity at the part of this composite band corresponding to the Compton change of wave-length h vers ϕ/mc is compared with the intensity of the unmodified line, assuming a certain resolving power of the spectrometer. The theory shows that this relative intensity increases with increasing scattering angle, decreases with increasing atomic weight of the scatterer, and decreases with increasing wave-length of the primary rays. For light scattered by paraffin the relative intensity of the modified band is zero. The theory thus qualitatively explains the effects observed by Compton, Ross and Duane.

FRIDAY AFTERNOON AT 2 O'CLOCK

East Building

13. Power series which facilitate the evaluation of certain integrals. N. ERNEST DORSEY, Washington, D. C.—In determining the value of correction terms, or the effect of small changes in the value of certain coefficients, the experimental physicist now and again has to express an integral of the form ${}_0\int^1[(1+ax)(1+bx)^{k+1}]^{-1}dx$ as an ordered series of powers and products of a and b. While the formal integration is easy, the usual procedures lead to a number of rational fractions and a logarithmic term, and the collection of the several powers and products is tedious and subject to errors which can not be readily detected. If, however, $-1<\epsilon>1$, $\epsilon=(a-b)/(1+b)$ which is the case with which the experimental physicist is usually concerned, then the general integral can be written down at once in the following convenient form: ${}_0\int^1[(1+ax)(1+bx)^{k+1}]^{-1}dx=[(-1)^k k!/(1+b)^{k+1}]\ [L_0(\epsilon)/k!+L_1(\epsilon)b/(k-1)!+\ldots.+L_n(\epsilon)b_n/(k-n)!+\ldots.+L_{k-1}(\epsilon)b^{k-1}+L^k(\epsilon)b^k]$, where $L_0(\epsilon)=1-\epsilon/2+\epsilon^2/3-\epsilon^3/4^+\ldots.$; $L_n(\epsilon)=\sum_0^\infty(-1)^m m!\epsilon^m/[(m+n+1)!]=(1/\epsilon^{n+1})\ {}_0\int^\epsilon\ldots.\ {}_0\int^\epsilon\log(1+\epsilon)\ (d\epsilon)^n$. The L's appear to be functions hitherto unrecognized.

14. Metallic potassium as a mercury vapor trap. A. LL. HUGHES and F. E. POINDEXTER, Washington University.—The alkali metals absorb mercury vapor strongly. The pressure as indicated by an ionization gauge when connected directly to a condensation pump is reduced about 12000-fold by the introduction of distilled metallic potassium into the tube between the gauge and pump. This reduction is of the same order as that obtained by a liquid air trap in place of the potassium. A tube was made up containing helium at about 1 mm pressure. One end of the tube contained electrodes whereby a discharge could be passed through the gas, the middle was lined with distilled metallic potassium, and the other end contained mercury. For a number of weeks, the spectrum of the discharge showed no trace of mercury lines, indicating that the potassium lining the middle part of the tube formed a satisfactory barrier to the passage of mercury vapor. After ten weeks, during which nearly 1 cc of mercury had evaporated and had been absorbed by the potassium, faint traces of a few prominent mercury lines were observed in a strong discharge. This severe test shows that the potassium is still a powerful absorber of mercury vapor after it has absorbed a considerable quantity.

15. On the kinetic theory of thermionic effect. N. P. RASHEVSKY, Westinghouse Elec. and Mfg. Co. (introduced by A. P. Wills).—Making different assumptions on the behaviour of electrons inside a solid body, statistical deductions of the expressions for

the thermionic current are made in the corresponding cases. All the formulas obtained are of the type: $i = AT^a e^{-b/T}$, but differ by the values of the constants. The influence of the different assumptions on the value of a is investigated. The following results are obtained: (1) If the electrons inside the body behave like a perfect gas, $a = \frac{1}{2}$. This result holds whether the quantum theory is used or not. (2) If the electrons inside the body are arranged in space-lattices with the same dynamical properties as ordinary crystal-lattices, the *classical* treatment of the problem leads to $a = -1$. (3) If all electrons are moving in quantized orbits with the same quantum number and energy, $a = 2$. It is shown both thermodynamically and statistically, that in general $a = 2$ may be obtained as an approximation only by neglecting the specific heat of the inside electrons. Some recent experimental results are discussed.

16. The thermionic emission from substances containing iron and alkali metal. C. H. KUNSMAN, Fixed Nitrogen Research Laboratory.—The thermionic emission of certain substances consisting primarily of iron and alkali metal has been investigated. They have been found to be constant sources of positive and negative emission. The positive emission was identified as singly charged positive ions of the alkali metals. Both positive and negative emission followed Richardson's equation $i = AT^{\frac{1}{2}}\epsilon^{\varphi e/KT}$. Values of φ were obtained from this equation for temperatures of 672° to 1110° Kelvin. φ_+ for the positive charged K-ions vary from 2.04 to 3.41 volts, depending on the substance and its previous gas treatment. φ_- was determined as 4.00 volts for the electron emission for the case where φ_+ was 3.41 volts.

17. Comparison of thermal electron emission from a pool of caesium and from adsorbed films. K. H. KINGDON, General Electric Company.—The emission from a pool of Cs freed as much as possible from occluded gas is about 5.5×10^{-13} amp./sq. cm at 450° K and 2.5×10^{-11} at 500° K. At 475° K the presence of 0.016 mm pressure of hydrogen raised the emission about 3-fold, while the presence of 0.1 mm pressure of argon decreased the emission to about 70 percent of its value in vacuum. On account of the effects of adsorbed gas the slopes of the temperature characteristics cannot be used to determine the work-function. The tablet gives a comparison of emissions in amp./cm² from the pool of Cs and from adsorbed films of Cs.

Source	Temp. of bulb	Emission at 600° K	at 500° K
Cs absorbed on oxygen film on tungsten	−184° C	4.7×10^{-8} (obs.)	1.8×10^{-4} (extrapol.)
Same	+100° C	1.5×10^{-5} "	2.4×10^{-6} "
Cs absorbed on tungsten	+80° C	5.6×10^{-7} "	5.6×10^{-11} "
Pool of Cs			2×10^{-11} (obs.)

18. Variation of the photo-electric effect with temperature in the alkali metals. HERBERT E. IVES and A. L. JOHNSRUD, Bell Telephone Laboratories, Inc.—Special cells having a hollow central cathode were immersed in liquid air for an extended period to condense any gases present on the outer alkali metal coated walls. By a stream of evaporating liquid air, the temperature of the cathode was held at temperatures between +20 and −180° C. In these cells the variation of photo-electric current with temperature in sodium, potassium and rubidium is continuous. The effect is relatively small for sodium, showing hardly at all for blue light or white light, but clearly for yellow light. The behavior of rubidium is similar to that previously reported for potassium. In a second form of cell, potassium was collected in a deep pool. By slowly cooling the metal from the molten condition, smooth crystalline surfaces were obtained. With these annealed potassium surfaces, the variation of photo-electric current with temperature is represented by curves varying systematically in shape with the color of the light, and

the effect is far greater than previously reported, amounting, for yellow light, to a variation of 10 to 15 times between room and liquid air temperature. When the surface is roughened curves of the previously reported type are obtained. Small pools give erratic effects, showing changes in opposite directions for different portions of the temperature range. It is concluded that the variation of photo-electric effect is intimately connected with the strains produced in the surface by expansion and contraction with temperature.

19. Photo-electric threshold and light absorption. J. J. WEIGLE, University of Pittsburgh.—The coefficient of absorption of light in metals (determined directly in thin films or from the optical constants of the metal) shows a sharp discontinuity for a certain wave-length. This is explained by the fact that at this wave-length the emission of photo-electrons starts. The quantum theory of equilibrium between radiation and photo-electrons developed by Kramers and Milne seems to apply here. The absorption curve thus gives a new way to determine the photo-electric threshold. From the values of the coefficient of absorption taken from Landolt and Bjornstein Tables the following long-wave-length limits have been calculated: Co 3450, Cu 3250, Ag 3300, Au $<$2570, Mg 4300, Zn 4400, Al 4400, Ni 3540, Fe 3450, Na $>$6750. These are in fairly good agreement with the observed values. A careful study of the absorption of light in metals will give valuable information as to electrons in metals.

20. Comparison of the thermionic work functions and the photo-electric thresholds. RICHARD HAMER, University of Pittsburgh.—A comparative study of the tabulated values of the observed thermionic work functions and photo-electric thresholds for all the elements indicates that a connecting relation of some kind exists. The reliable thermionic ϕ is generally a little lower than the threshold value V_0. The author has previously pointed out that the true thresholds correspond to a critical potential or to the ionizing energy for some critical level, in each sub-group. Obviously the thermionic ϕ must do likewise which further supports the theory that the electrons form an interionic electron lattice such that electron distance to the nearest positive metallic ion corresponds to the radius of a fundamental spectroscopic orbit for each sub-group. The ideal and true thermionic ϕ may be considered similarly to the photo-electric V_0 as the lower limit of the series of values of the potential energies of electrons in such a lattice, ranging from one practically free (as in a vapor state) to one buried with other lattice units extending in all directions to infinity with all possible orientations. A critical study of the defects from the similar photo-electric work function should enable one to relate the work function to the unit distance of the electron lattice for in the thermionic case the lattice is extended by temperature a determinable amount.

21. Atmospheric-electric observations made at New Haven during the total eclipse of January 24, 1925. W. F. G. SWANN, Yale University.—Measurements of the potential-gradient were made with a water-dropper, and measurements of the residual ionization in a closed vessel were made by a compensated scheme of high sensitivity. The potential gradient results give indication of a depression in the general rise of the curve which is characteristic of the early morning, and the residual ionization shows fluctuations about a mean value during the period of the eclipse. These fluctuations are very much more marked than those shown by any other portion of the curve or by the curves obtained on subsequent days.

22. The variation of the declination during the solar eclipse of January 24, 1925, at Urbana, Illinois. CHAS. T. KNIPP, University of Illinois.—Declination readings, similar to those of June 8, 1918 (Terr. Mag., **24**, Sept. 1918), were made during the eclipse of last January. The position of Urbana, Illinois, being about midway between

the two paths, made observations at the time of this eclipse desirable. The variometer used in 1918 was again used. The observations continued over a period of six hours and were made at one minute intervals. For comparison similar series were taken on the following day (Sunday) and again on the following Saturday. Five-minute averages of the declination readings were plotted against time. Thus a curve was obtained for each series. The two curves for the undisturbed days were combined by superposing one upon the other and drawing a resultant curve. The curve for the eclipse day was now superposed upon this resultant. Finally a ΔD curve was drawn in which the ordinates were the differences between the eclipse curve and the resultant curve referred to above. Comparing these two curves leaves but little doubt as to the effect of the eclipse. The disturbance seems to have preceded the shadow and also to have continued for some hours after. This in general is in agreement with the findings for the 1918 eclipse.

23. Measurements of illumination and color temperature at Washington during solar eclipse, January 24, 1925. IRWIN G. PRIEST, K. S. GIBSON and F. K. HARRIS, Bureau of Standards.—Two sets of observations were made at the Bureau of Standards, (Longitude, 77°4′0″; Latitude, 38°56′30″N) namely, one set on direct sunlight illumination on a surface normal to the sun's rays and one set on illumination from a part of the north sky. Measurements were made by the method of rotatory dispersion (J.O.S.A. and R.S.I., **7,** 1175-1209, 1923). The results will be shown graphically. The following are their salient features: (1) The sky data show a more regular systematic agreement with the phases of the eclipse than the data on direct sunlight. (2) The minimum illumination was about 3.1 percent of normal illumination at the same hour under the same conditions with no eclipse. (From sun data, 3.07 percent; from sky data, 3.24 percent.) (3) Since at the time of maximum obscuration 5.4 percent of the sun's disk was exposed, the average brightness of this portion of the disk is 57 percent of the average brightness of the whole disk. (4) There is a color temperature minimum at maximum obscuration as would be expected. (5) There are also two unexplained minima in illumination and color temperature occurring respectively before and after maximum obscuration. They may be secondary effects of the eclipse due to changes in the earth's atmosphere. The application of these data to the determination of the time of maximum obscuration will be considered in a separate paper.

FRIDAY AFTERNOON AT 2 O'CLOCK

Industrial Building

24. Binaural beats. C. E. LANE, Bell Telephone Laboratories, Inc.—Two types of binaural beats have been found; namely, objective and subjective. *Objective binaural beats* are heard for most frequencies within the audible frequency range, provided there is the proper amplitude ratio (about 1:1000) between the beating tones. These beats are the result of the conduction of the louder tone through the head to the ear of the weaker tone. *Subjective binaural beats* are heard for frequencies below 800 or 1000 cycles when the tones at the two ears have approximately the same amplitudes. They are undoubtedly the result of the sense of binaural localization of sound by phase. If the beats are slow they are generally recognized as an alternate right and left localization. Fast beats are generally recognized as an intensity fluctuation. They are explained by assuming that the sound appears louder when the phase relations are such that it is normally best localized in the position toward which the attention is directed.

25. Reverberation in auditoriums. F. R. WATSON, University of Illinois.—By sounding an organ pipe in various auditoriums and using calculated values of the volume and absorbing surfaces, an experimental confirmation has been made of the reverberation formula of Jäger. The experimental data has been used to formulate a relation showing that for good acoustics the time of reverberation may vary with the cube root of the volume of the auditorium (Jour. Frank. Inst., July, 1924). This relation, in turn, has led to the development of a nearly linear relation between the volume of the room and the amount of sound absorbing material needed to give good acoustics.

26. Note on de Sitter's universe. G. LEMAITRE, Massachusetts Institute of Technology (introduced by Paul Heymans).—De Sitter's solution of the relativistic equations of the gravitational field in the absence of matter introduces a spurious in homogeneity which is not simply the mathematical appearance of center of an origin of coordinates, but really attributes distinct absolute properties to a particular point. A new form of de Sitter's solution is given in order to remove this difficulty. New coordinates are introduced and, with the corresponding separation of space and time, the field is found homogeneous but non-statical. Furthermore the geometry is euclidean. The singularity at de Sitter's horizon disappears. The Doppler effect has the numerical value given by Silberstein, but no way is found of introducing his double sign without spoiling the homogeneity of the field. The result that a homogeneous solution of de Sitter's world is non-statical and euclidean is rather against the physical significance of de Sitter's universe. However, the non-statical character of this universe has been advocated as an advantage by Eddington, but euclidean geometry is a very unsatisfactory feature of any conception of the whole universe.

27. The application of the calculus of perturbations to atomic systems and the adiabatic principle. M. SANDOVAL VALLARTA, Massachusetts Institute of Technology. —The applicability of the calculus of perturbations to atoms with more than one electron is examined in detail. It is shown that Poincare's classical theorem may be stated as follows: Except for the dynamical system of one degree of freedom, no continuous analytic hypersurface exists in phase-space, besides the energy-surface, which contains wholly a dynamical trajectory issuing from one of its points. Correlating this with a theorem already stated by Fermi, that any dynamical system admitting a single integral uniform and independent of time admits an adiabatic transformation leaving this characteristic invariant, it is concluded that for continuity reasons neither the method of quantization of Epstein nor that of Born and Pauli are in general compatible with the adiabatic principle. This conclusion holds together with the well-known fact that neither of these methods converges. In agreement with a recently published paper of Wataghin and in answer to a question proposed by Ehrenfest, it is shown that in general all dynamical systems having a degree of periodicity grea er than the number of degrees of freedom admit no energy integral and hence are of no importance in current atomic theory.

28. Mechanical aspects of the Bohr atom. F. S. BRACKETT and L. B. SNODDY, University of California.—Orbital dimensions obtained by the method developed by Hartree together with the structural data from the field of x-rays and crystal structure furnish information in regard to the number of free electrons. This forms the basis for computation of the relative conductivities of metals. The substantial agreement of these with the experimental values supports the view that the Bohr atom may be regarded as a mechanical picture. The solution obtained for the copper atom supports Bohr's assignment of quantum designation. "Broken series" are to be expected in the cases of those associated with the p terms instead of the d terms as proposed by Wentzel. The d terms and part of the p terms are shown to be hydrogenic and so do not fall under the law of proportionality between quantum defect and the number of orbital groups established for the penetrating orbits.

29. Radiation pressure and Fermat's principle in the quantum theory. J. C. HUBBARD and R. T. COX, New York University.—Quanta of energy $h\nu$ with momenta in vacuum $h\nu/c$, normally incident on a totally reflecting surface, will, by the conservation of momentum, exert on the surface a pressure equal to the energy density. If the statistical velocity of a quantum in any medium be v, the velocity of light in that medium, it is necessary and sufficient, in order to account for the observed normal and tangential components of radiation pressure on the boundary between two media, to ascribe to the quantum a momentum $h\nu/v$. This value for the momentum being used in the principle of least action, Fermat's principle is obtained, and the paths of reflected and refracted rays are thus accounted for.

30. On the motion of Faraday's lines of force. H. BATEMAN, Norman Bridge Laboratory of Physics.—In J. J. Thomson's theory of moving lines of electric force the velocity v of a point of the moving line can be any velocity satisfying the relation $cH = v \times E$ where E, H, c are the electric force, magnetic force, and velocity of light, respectively. In the field of a moving electric pole the velocities, of magnitude less than c, satisfying this relation are the velocities which a particle could have if it were formed by the union, without any loss of energy or momentum, of two light-particles with energies $(mc^2, m'c^2)$ and momenta $(mc, m'c)$, where m and m' are any two positive quantities having the dimensions of mass. The velocity of each light-particle is of magnitude c and satisfies the equation for v. Various laws of distribution for m and m' are considered and also laws of distribution for v.

31. Heaviside's theory of electric networks. N. WIENER, Massachusetts Institute of Technology (introduced by M. S. Vallarta).—The author seeks a mathematical justification for the asymptotic solutions for large values of the time which Heaviside obtains for currents and voltages in electrical networks. Like T. C. Fry, he makes use of a generalization of the Fourier integral. He separates voltages and currents into high and low frequency bands and finds that the low frequency regions determine the asymptotic behavior of the system. His method of interpreting the Heaviside operators is in harmony with that of J. R. Carson in systems where there are no negative resistances, but not, in general, in other cases. This is the source of the real discrepancies sometimes observed in Heaviside's theory between the expansions in powers of t and those in powers of $1/t$. In addition, apparent discrepancies arise from a misunderstanding of the nature of asymptotic expansions.

32. Electric capacity and conductivity of blood for frequencies between 800 and 4.5×10^6 cycles. HUGO FRICKE, and STERNE MORSE, Cleveland Clinic.—Measurements were made with a bridge using a substitution method, the capacity and resistance of the blood being compared with those of a liquid having the same specific resistance for a given frequency. At low frequencies one cubic centimeter of blood of normal concentration is equivalent to a resistance in parallel with a capacity of a few hundred micromicrofarads; for increasing frequencies the decreases in resistance and capacity are nearly in accord with the following formulas: (1) $R = C_1^2w^2R_1^2/R_1(1+C_1^2w^2R_1^2) + C_2^2w^2R_2^2/R_2(1+C_2^2w^2R_2^2)$; (2) $C = C_1/(1+C_1^2w^2R_1^2) + C_2/(1+C_2^2w^2R_2^2)$. C_1, R_1 and C_2, R_2 correspond to two perpendicular principal orientations of a red corpuscle. A red corpuscle may be considered as a well conducting interior phase surrounded by a thin poorly conducting membrane, the static capacity of which is responsible for the capacity of the blood. By (1) the resistance of the blood for $\omega = \infty$ can be calculated. This resistance is equal to the resistance which would be obtained at lower frequencies if the membrane could be removed without disturbing the inside of the corpuscle. From the value of this resistance the specific resistance of the interior phase of the corpuscle, is by an earlier formula calculated to be about 25 percent of the specific resistance of the serum for the case of dog, sheep, calf or rabbit.

33. The electric network equivalent of a piezo-electric resonator. K. S. VAN DYKE, Wesleyan University.—Starting with the fundamental differential equations given by Cady (Proc. I. R. E. **10**, 83, 1922) for the current to a piezo-electric resonator and for the forced vibrations of the resonator under an applied alternating potential, it has been shown that so far as the circuit is concerned the crystal itself may be replaced by a series combination of inductance $M/4\epsilon^2b^2$, capacity $4\epsilon^2b^2/g$, and resistance $N/4\epsilon^2b^2$. In parallel with this series combination is a capacity which, when the electrodes are close to the crystal and of the same area, is $(k/4\pi-\delta\epsilon)bl/e$, the first term being associated with the ordinary dielectric displacement and the second with the static piezo-electric displacement. M, N, and g are the equivalent mass, frictional coefficient and stiffness of the crystal regarded as a rod having but one degree of freedom, l, b, and e its length, breadth, and thickness, while k, ϵ, and δ are the dielectric constant, and the piezo-electric constant and modulus respectively, all in c.g.s. and electrostatic units. For Cadys quartz plate N2 ($3.07\times0.41\times0.14$ cm), which has a fundamental frequency for longitudinal vibration of 90,000 cycles per second, the elements of the series combination expressed in practical units are 140 henries, 0.023 micromicrofarads, and 16,000 ohms, while the parallel capacity is $(3.6-0.031)$ micromicrofarads. The problem of a vacuum tube circuit containing the crystal is now being investigated by this method.

SATURDAY MORNING AT 10 O'CLOCK

East Building

34. Analysis of the "Comet tail" bands. C. M. BLACKBURN, University of Chicago (introduced by Harvey B. Lemon).—The interesting bands first noticed in the tails of certain comets and later produced in the laboratory by Fowler and ascribed by him to low pressure CO have been obtained with sufficient intensity to allow of their photography under high dispersion by the method of excitation recently developed by Lemon. Of the eleven bands assigned to the system, nine have been photographed in the first order of the 21-foot Rowland concave grating with times of exposure ranging from 20 to 48 hours. The other two bands were too faint to be photographed with this dispersion. Each comet tail band consists in reality of two rather strong bands, separated about 115 wave-numbers, each of which has a satellite band, usually poorly developed, about 15 wave-numbers to the violet. The bands all degrade toward the red, and are particularly characterized by the absence of any Q branch. The rotation term is parabolic within the limits of experimental error. Neither the rotation nor vibration terms of this system seem to correspond in any way with those of the Deslandres' First Negative System, although the experimental connection between the two systems seems to be definitely established.

35. The excited states of the CuI molecule, and the band spectra of certain salts. ROBERT S. MULLIKEN, Harvard University.—The CuI spectrum is now found to consist of five systems of bands. Each corresponds to a transition to the normal state from one of five excited electronic states, corresponding respectively to energies of 2.44, 2.68, 2.70, 2.83, and 2.96 volts. Similar relations probably hold in CuBr and CuCl. It is likely that the excited electron belongs to the Cu^+ ion; its easy excitation can then be correlated with the existence of bivalent copper compounds like Cu^{++} Cl^-_2. This is in harmony with the complete absence of electronic band spectra in the case of the alkali (and hydrogen) halides, whose positive ions M^+ contain no easily excited electron and never are bivalent; and notably also with the absence of silver halide band spectra, silver being closely related to copper, but differing in the non-occurrence of bivalent compounds. Attempted excitation of an electron in the *negative* ion in these compounds presumably

leads to break-up of the molecule. Since the Me^{++} ion in $Me^{++}X^{-}_{2}$, like the M^{+} ion in the alkali halides, contains no loosely bound electron, the familiar band spectra of the alkaline earth halides should, by analogy, not be due to MeX_2 molecules. Instead they may be ascribed to diatomic compounds $Me^{+}X^{-}$ containing one unused loosely bound valence electron.

36. The spectrum of lithium hydride. WILLIAM W. WATSON, University of Chicago.—A lithium arc in a hydrogen atmosphere at reduced pressure was used to excite a spectrum, extending from λ5000 down to about λ3200, which is in part undoubtedly due to the LiH molecule. This spectrum is of a complex character and resembles the secondary hydrogen spectrum in that there are no apparent band heads. Partial bands have been found which indicate that the moment of inertia of the LiH molecule is about 6×10^{-40} gm cm.^{2} It is shown that the relative sizes of this and other molecules as determined by band spectra measurements are in accord with relative molecular and atomic radii computed by other methods.

37. Spectrum of the condensed spark in aqueous solution. E. O. HULBURT, Naval Research Laboratory, Washington, D. C.—A visual examination in the visible spectrum and a photographic examination in the ultraviolet from 3200 A to 2400 A of the spectra of the condensed spark in dilute water solutions of metallic salts have been carried out. Dilute solutions, about 0.2 percent, of salts of Al, Sb, As, Ba, Bi, Br, Cd, Ca, Cr, Co, Cu, I, Fe, Pb, Li, Mg, Mn, Hg, Mo, Ni, K, Na, Sr, Sn, and Zn, were used. The D lines of sodium in the NaCl solution appeared as absorption lines, widening with concentration as they should according to the Stark quantum theory of broadening. No other prominent absorption lines were produced by the dissolved salt, although a number of weak absorption lines have not yet been identified. Further investigation is in progress and may modify these conclusions. Phosphor bronze and duralumen (a silicon aluminum alloy) served as spark electrodes, for these metals disintegrated slowly and produced few absorption lines. Incidentally, the use of duralumen electrodes has enabled the water spark spectrum of silicon to be observed; this has not been done before because of the rapid splintering of a pure silicon electrode.

38. Term regularities in the arc spectrum of tungsten. OTTO LAPORTE, Research Fellow Bureau of Standards (introdued by W. F. Meggers).—Various investigators having studied the elements of the first and second long period and confirmed Sommerfeld's and Lande's laws for the multiplets, it seemed to be desirable to extend the investigation to the heavier elements. The element tungsten ($Z=74$) was chosen since it is in the same column as 24 Cr and 42 Mo, which are of a rather simple spectral type as shown by Kiess and by Catalan. While Cr and Mo have as lowest term, a septet s-term and nearby S- and D-terms of the quintet system, in tungsten the lowest in the D-term with the s-term lying between its levels. The separations of the D-term are 1670.25; 1655.25; 1504.50; 1389.30 (in Mo resp. 177; 312; 404; 488; in Cr 60; 117; 168; 212). The interval rule is not fulfilled. Although the identification of these lower terms is unambiguous as to their quantum numbers and g-values, it was not possible to ascribe azimuthal quantum numbers to all the numerous higher levels combining with s and D, and to arrange the levels in polyfold terms, because of the very large separations, the failure of the interval rule and of Landé's g-formula. The analysis in its present state classifies about 200 W-lines as combinations of only the s and D-terms with higher levels.

39. On the origin of spectral doublets. WILLIAM V. HOUSTON, Ohio State University.—If it is assumed that the two terms of a spectral doublet are due to two opposite positions of the orbit of the series electron, the doublet separation is then due to the

magnetic field of the series electron, and is expressed by the same function as the relativity separation, except that the effective nuclear charge appears to the third power instead of the fourth power. The data of Bowen and Millikan on the stripped atoms from lithium to nitrogen fits the relativity law very well. Their data on the elements from sodium to chlorine is shown to fit a third power law much better, and with a third power law to give shielding constants which are more compatible with the known term values. With increasing atomic number the power of the effective nuclear charge, with which the doublet separation seems to vary, decreases until with silver and cadmium it is between the first and second power. The *d* doublet separations are expressed as well by the magnetic law as by the relativity law. It can be concluded that optical doublets are not due to relativity, but that the magnetic and other interactions of the electrons must be taken into account.

40. Relations of pp′ groups in atoms of the same electronic structure. I. S. BOWEN and R. A. MILLIKAN, Norman Bridge Laboratory of Physics.—A so-called *pp′* spectral group consisting of a quintuplet of nearly equally spaced lines has heretofore been found in Ca, Ba, Sr, Mg, Al_{II} and Be. We have found this characteristic structure in all the two-valence electron systems which we have studied by the method of hot-spark spectroscopy, namely in the two-valence electron series Mg_I, Al_{II}, Si_{III}, P_{IV}, S_V, Cl_{VI}, and in the other two-valence electron series Be_I, B_{II}, C_{III}, N_{IV}, O_V. In both of these series this *pp′* group has been definitely shown to arise from an electron jump from the lowest *p* to the lowest *s* orbit, combined with a simultaneous jump between the p_1, p_2, p_3 orbits. We have discovered a new quadruplet *pp′* group characteristic of all three-valence electron systems, and have located it in all the members of the three-valence electron series, Al_I, Si_{II}, P_{III}, S_{IV}, Cl_V, and the further three-valence electron series C_{II}, N_{III}, O_{IV}. This quadruplet *pp′* group has been proved to be due to the return of one of the *s* electrons after it has been displaced to a *p* position combined with the simultaneous interchange of the *p* electron between the p_1, p_2 orbits.

41. The spectrum of neon in the extreme ultra-violet. T. LYMAN and F. A. SAUNDERS, Harvard University.—The known ionization potential of neon, 21.5 volts, indicates that there should be series of lines converging to a limit about λ575. Photographs of the spectrum of moderately excited neon below λ1250 show a pair of lines of very great strength, whose frequency difference is that of Paschen's terms s_2 and s_4. Other lines occur whose frequencies show that they are combinations with *d* terms, indicating that the fundamental level is a *p* term, and of inner quantum number 0, in Landé's scheme. The lines found are the combinations of this $1p$ term with the following terms: $1s_4$ at λ743.78; $1s_2$ at 735.95; $2s_4$ at 629.80; $2s_2$ at 626.79; $3d_2$ and $3d_5$ (not resolved) at 618.92; $3s'_1$ at 615.62; $3s_4$ at 602.78; $2s_2$ at 600.08; $4d_2$ and $4d_5$ (not resolved) at 598.88; $4s'_1$ at 595.92; $4s_4$ at 591.85 and $5d_2$ and $5d_5$ (not resolved) at 589.91. These series appear to converge to two different limits, whose frequencies are near 173918 and 174699, corresponding to ionization potentials of 21.466 and 21.562 volts. The argon spectrum seems to have a similar structure, and comparison between these two has facilitated the elimination of lines due to unknown impurities. Both Ne and A give complex spectra in disruptive discharges, extending at least to λ350 and λ380 respectively.

42. The relative times of first appearance of certain bright spectrum lines. F. L. BROWN and J. W. BEAMS, JR., University of Virginia (introduced by L. G. Hoxton).—The spark in air was studied. The nitrogen group of *air* lines 5002 appeared first then the 5667-80 group, followed by metallic lines in sequences as follows: For Cd the spark doublet 5378,38 appeared first, followed by the sharp arc triplet 5086,4800,4678; finally the diffuse singlet arc line 6438. For Mg, first the spark doublet 4481, then the sharp

arc triplet 5184,72,67. For Zn, first the spark doublet 4924,12, then the sharp arc triplet 4811,4722, 4680, next the diffuse spark lines 6103,6022, finally the diffuse arc singlet 6362. A preliminary quantitative determination of the time interval indicates that the Cd spark doublet lines appear about 3×10^{-8} second before the Cd sharp triplet arc lines. The apparatus is a modified form of that used by Abraham and Lemoine and others for measuring short time intervals.

43. Double electron transitions and primed spectral terms. ARTHUR E. RUARK, Bureau of Standards.—This research answers two questions in the affirmative: (1) Can an impacting electron ionize an atom and raise the valence electron of the ion to a higher orbit? (2) Can two electrons of an atom be raised to higher orbits by a single inelastic collision? Spectra of low voltage arcs in cadmium and magnesium were obtained at current densities less than 0.5 milliampere per square centimeter. At such densities magnesium spectra show no lines produced by phenomena of successive excitation. The pp' group (2776 to 2783 A) appears at its quantum voltage, as do also the lines of the spark spectrum, without regard to the nature of their classification; the sole condition for their appearance is that the impacting electron shall have sufficient energy. A number of Cd lines, including the pp' group, were classified, together with several lines of neutral indium and thallium which involve primed spectral terms.

44. The excitation of the ultra-violet band of ammonia. C. T. KWEI, Princeton University.—Storch and Olson found that in a simple two electrode tube with a hot filament as cathode, NH_3 was formed only when the arc struck in a mixture of hydrogen and nitrogen (Jour. Am. Chem. Soc., **45,** 1605, 1923). A similar apparatus with some modification was employed by the writer with the purpose of correlating the current voltage characteristics with spectroscopic observations. Two distinct breaks were found in the curve for a mixture of hydrogen and nitrogen, with the former very much in excess. Photographs of the spectrum taken through a quartz window attached to the side of the tube, showed that the so-called ultraviolet band of ammonia at about 2360 came out distinctly only after the second break and was invisible before the second break, which is at 22.5 volts. It is assumed that NH_3 is formed in increased amounts, owing probably to the presence of atomic nitrogen, at this potential. This is supported by the fact that the moment of inertia calculated from the relation $\Delta\nu = h/4\pi^2 I$ based upon Fowler's measurement of the band (Phil. Trans. A. **218,** 351, 1919) indicated that the radiating molecule could not contain more than one atom of nitrogen. The critical potential at 22.5 volts is roughly in agreement with the 24 volts potential observed by Smyth (Proc. Roy. Soc. **104,** 121, 1923) and the 25.4 potential observed by Bazzoni and Waldie (Jour. Frank. Inst. **197,** 57, 1924).

SATURDAY MORNING AT 10 O'CLOCK

Industrial Building
Room 353

45. Observations on the "hydrogen point" in iron. HENRY S. RAWDON and PETER HIDNERT, Bureau of Standards.—It is well established that electrolytically deposited iron may be profoundly affected by the presence of hydrogen, also that hydrogen diffuses readily through heated iron. Incident observations on the hydrogen point have been reported by metallurgical investigators. The authors have been unable to find any published account, however, of systematic observations on the "hydrogen point" in iron or the explanation of "anomalies" in the properties of iron resulting therefrom. The occasion for the investigation was to check conclusions published by

Sirovich (Gazetta Chimica Italiana, October 1923) concerning a "new" polymorphic transformation in ferrite, 373° C, based upon dilatometric measurements. The authors' study of iron annealed (1) in an open furnace, (2) in vacuum, and (3) in an atmosphere of hydrogen, shows that heated iron absorbs and retains a very appreciable amount of hydrogen. Thermal analyses demonstrate in the heating curve a heat evolution beginning at 325° C (approximately) and reaching its maximum at 380° C (approximately). Likewise, thermal expansivity curves of hydrogen-treated iron show a "disturbance" in this temperature range whereas the same specimen annealed in vacuum gives a very "smooth" expansion curve. The results do not support the conclusions of Sirovich concerning a low-temperature polymorphic change in ferrite.

46. The latent heat of vaporization of liquid oxygen-nitrogen mixtures. LEO I. DANA, Laboratory of The Linde Air Products Company, Buffalo, N. Y.—This work, performed at the Jefferson Physical Laboratory, Harvard University, describes a continuous flow calorimeter for the latent heat of vaporization of binary mixtures and its application to mixtures of liquid oxygen and nitrogen. The heat quantity measured is the change in total heat from the liquid state at a definite composition x to the saturated vapor state at the same composition, at constant pressure, but with a rise in temperature corresponding to the vertical separation of the vapor and liquid curves on the temperature-composition diagram. The latent heat of pure oxygen at one atmosphere was found to be 51.00 cal. (15° C) per gram, while that of pure nitrogen, 47.74 cal. per gram with an accuracy of 0.2 percent. The latent heat curve for the mixtures is represented by the equation $L=47.74+6.374x-0.2168x^2-2.887x^3$ in which x is the mole-fraction of liquid oxygen. It can be shown that the evaporation process for the mixtures is equivalent, except for some small terms, to the sum of the latent heats of the individual components and the heat required to superheat the vapor through the temperature difference between the two curves on the temperature-composition diagram. It thus results that the latent heat curve possesses a maximum.

47. Thermal conductivity and specific heat of lithium. CHARLES C. BIDWELL, Cornell University.—A lithium rod 1.1 cm diameter, 25 cm length, wrapped in a single layer of oiled paper was supported vertically in a test tube, 3.2 cm diameter, and heated electrically at the upper end by a small coil. Junction wires 3 cm apart along the rod gave temperatures. The tube was surrounded by various constant temperature baths and the temperature gradients observed. Curves were obtained for the rod when cooling to these various external temperatures. Cooling curves were also obtained for a copper rod of same dimensions and similarly wrapped. By applications of Newton's law of cooling and the equation that rate of heat supply per cm length equalled rate of heat escape from the surface per cm length, thermal conductivity was computed. From the cooling curves for copper and lithium and the known specific heat of copper, specific heat of lithium was determined. Thermal conductivity increased apparently from zero at the absolute zero to a maximum of 0.31 at −50° C, decreasing again to some very small value at the melting point. The specific heat increases from about 0.6 at −183° C approaching asymptotically to a maximum of about 1.1, its value at +150° C being about 1.05.

48. Variation of heat loss with gas pressures. CHARLES F. HILL; Westinghouse Elec. and Mfg. Co., East Pittsburgh.—The amount of heat carried away by air at various pressures from one atmosphere down to very low pressures has been measured for a wire axially placed in a horizontal cylinder 8 inches in diameter. For this case it is found that the results agree fairly well with those of Kennelly, the exponent of pressure being about .3 instead of the theoretical value of .5. However, for low pressures of the

order of 1 mm the loss varies as the square root of P until the pressure is reduced to a value such that the mean free path of the gas molecules is greater than the radius of the cylinder. The losses then vary directly as the pressure. Extrapolation of the losses for such low pressures give the radiation losses. From this the radiation constant can be determined, and such a method is found adaptable to determine the radiation constant for insulating materials and surfaces used in electrical machines. Knudsen's equation for molecular conduction is found to check with the above extrapolation.

49. A newly-found difficulty with the mercury-contact thermostat. WALTER P. WHITE, Geophysical Laboratory.—Merits of a thermostat may be *steadiness*, or smallness of the temperature fluctuations occurring within a few seconds or minutes, and *constancy*, or smallness in the variation of mean temperature from day to day, brought about chiefly by change in room temperature. Backlash in the mercury-to-wire contact creates unsteadiness, but not inconstancy. Lag causes both. If the temperature alternations are greatly accelerated, as by oscillating the contact wire (Gouy) or by putting the bulb very near the heater, steadiness is increased. Constancy is usually diminished at the same time. But the effect of lag in producing unsteadiness has been supposed to be completely overcome. The present investigation shows the contrary. A Gouy thermostat may hunt indefinitely, and may begin hunting immediately after the temperature has been adjusted to equilibrium value. It is lag in the stirring that produces this hunting. External lag of the bulb does not; internal lag, probably not. In one case, external bulb-lag having the extraordinary value of 7 minutes, plus a stirring lag of 4 seconds, caused only one-third as much hunting as with stirring lag 16 seconds, plus bulb lag of half a minute. The hunting is diminished by increasing the throw of the wire, and therefore at the expense of further inconstancy. With bulbs near the heater similar actions may occur.

50. Martian temperatures computed from water-cell transmissions. D. H. MENZEL, W. W. COBLENTZ and C. O. LAMPLAND, Bureau of Standards.—By this method (described in the Astrophys. Jour., **58**, 65, 1923) the temperatures are derived from the fourth-power law of total radiation. The various factors, e.g. albedo, water-cell transmission, atmospheric absorption, etc., enter as the fourth-root in the equation, which minimizes the errors of observation. An uncertain factor is the albedo of the isolated areas upon which the radiometric measurements were made. The average temperature of the whole disk of Mars was $-30°$ C. The temperatures of the apparent center of the disk ranged from $-5°$ C on the bright areas to $+22°$ C on the adjacent dark areas; the predominating values being 6° C to 9° C. The true temperatures would be about 10° higher, or 15° to 20° C. At opposition the black body temperature of the east limb was $-55°$ C, the west limb $-7°$ C, the north pole $-110°$ C and the south pole $-90°$ C. After the Martian solstice (Oct. 5) the temperature of the south polar region increased to 10° C. The temperatures derived by this method of reducing the data are in good agreement with those obtained by three other methods all of which indicate conclusively that the equatorial temperature of Mars, at perihelion was considerably above 0° C.

51. The stress-strain properties of bakelite and the law of its optical behavior under mechanical stress. PAUL HEYMANS and T. H. FROST, Massachusetts Institute of Technology.—Ambronn, Ramspeck and Wächtler have independently reported the hysteretic behavior of the stress-strain properties of celluloid and of its optical properties under mechanical stress. However, their conclusions that celluloid is therefore unsuitable for the photo-elastic method of solution of stress problems is unwarranted as the hysteretic effects can be eliminated by means of Coker's compensation method. As a material in which hysteretic behavior is absent would, however, be a decided

advantage, the authors present a preliminary report on their investigation on a composition of isotropic transparent bakelite (with absorption coefficient $k = .295$ cm^{-1} for mazda lamp illumination against 1.810 cm^{-1} for camphor-celluloid). The stress-strain curves are linear up to a stress exceeding 4000 lbs./sq. in., where the test members broke at the clips; the value of Young's modulus varies from 7 to 7.4×10^5 lb. per sq. in. The index of temporary double refraction due to stress (for definition see Heymans and Allis, Journ. Math. and Phys., M. I. T. II, **4**, 231, 1923), taken repeatedly over a period of several days, has averaged, without systematic variation, 41.33×10^{-10} cm^2 per gm for the sodium flame, with a maximum deviation from the mean of $+1.44$ and -1.09×10^{-10} cm^2 per gm; these deviations corresponding to the uncertainty of the applied load. The results show superiority for photo-elastic purposes over those for glass and celluloid and reveal no hysteretic behavior. The Brinell hardness number is 45 against 143 for .2 percent C steel.

52. Information regarding equilibrium in soda-lime and other glasses, obtained from viscosity measurements. G. S. FULCHER, Corning Glass Works.—Recently S. English has published the results of a very thorough study of the effect on the viscosity-temperature curve of replacing the soda in soda-trisilicate glass by CaO, MgO and Al_2O_3, molecularly. If the resulting change in log viscosity per molecule substituted is plotted as a function of temperatures, curves are obtained for each oxide which show a sharp bend upward as the temperature decreases through a temperature T_D, which is higher the greater the amount substituted. For each oxide the curves below T_D are parallel, indicating that the increase in the rate of stiffening of the glass due to the substitution is proportional to the amount substituted. The temperatures T_D are found to be about those at which we should expect the glasses to begin to devitrify, according to the equilibrium triangle for $Na_2O-CaO-SiO_2$ published by Morey and Bowen, although no signs of actual devitrification were observed. Values for T_D were also obtained for other lime-soda glasses from the extensive results published by Washburn, Shelton and Libman. Viscosity measurements, then, can give us information as to molecular aggregation in glasses which we have been unable to obtain otherwise.

53. The viscosity of pure liquids under pressure. P. W. BRIDGMAN, Harvard University.—The effect of pressures up to 12000 kg/cm^2 on the viscosity of 43 pure organic liquids has been determined at 30° and 75° C. The viscosity increases under pressure. To a first approximation the viscosity increases geometrically as pressure increases arithmetically; i.e. log (viscosity) against pressure is very nearly a straight line. There is, however, a slight curvature which is more pronounced at the lower pressures; the direction of curvature is such that the log (viscosity) curve rises less rapidly at the high pressures, although there are some reverse cases, especially for substances with high absolute viscosity. The magnitude of the effect varies enormously with the substance; the viscosity of methyl alcohol increases 10-fold under 12000 kg, whereas that of eugenol increases millions of fold. The pressure effect is in general greater for the substances with the more complicated molecules. The temperature coefficient of viscosity also increases very markedly with increasing pressure. Viscosity is not, as some theories have supposed, a function of volume only, but at constant volume the viscosity is less at the high temperatures (and pressures). It seems plausible to ascribe the very high pressure effects to a sort of interlocking of the molecules.

54. Internal friction in solids apparently independent of strain velocity. A. S. KIMBALL, JR., General Electric Co.—When an overhanging shaft with a weight on its end is revolved, a slight transverse deflection is produced due to internal frictional hysteresis. By the use of this method, it is shown that internal friction in solids is not dependent,

as is usually assumed, upon the rate of change of deformation, like fluid friction, but that it acts like ordinary sliding friction. The internal frictional force is found to have substantially a constant value in nickel steel, carbon steel, copper, brass and celluloid for strain cycles of frequency ranging from one to thirty per second. It does depend upon the amplitude of the strain cycle, however, and is nearly proportional to it. It is found to reverse completely when the deformations are reversed in direction. Frictional force of this type, which is proportional to the amplitude of strain, gives an exponential law of amplitude decrement like that of the old theory, but the amplitude decrement per cycle is independent of the frequency. All rods tested were given both rotation and vibration tests. The internal friction constants obtained by these two different methods checked each other in every case on the basis of the above theory.

55. An approximate determination of the depth of compression in copper bars during impact. E. W. TSCHUDI, Johns Hopkins University.—The author has previously shown that the duration of impact is a function of the relative initial velocity between the two bars and hence that the compressional wave theory is inadequate to explain their separation while a theory of local compression does seem reasonable. The present experiments were intended to measure the extent of this local compression in copper bars. It was found by copper plating steel bars that a thickness of copper of .038 mm and also one of .064 mm gave impact results similar to those of copper bars with the same mass and diameter. A thickness of .017 mm gave results between those of steel bars and copper bars. When the contact area is decreased, the duration of impact for steel bars varied inversely as the fourth root of the area. Collision with rounded ends resulted in smashing in the colliding ends. On the assumption that the pressure during impact varied as the sine of the time, a value of 2.66×10^{10} dynes was calculated, which is two and a half times the limit of elasticity tabulated for steel.

56. A new fabric tension meter. L. B. TUCKERMAN, G. H. KEULEGAN, H. N. EATON, Bureau of Standards.—It is frequently desirable to measure under various conditions the tension in a fabric or other membrane used as a part of a structure. Frequently only one side of the fabric is accessible. This is especially so in the case of the cover or envelope of an airship or the fabric covering of an airplane wing. A general relation exists between the tensions of such a fabric, its principal radii of curvature and the hydrostatic pressure acting on it, so that by measuring the deflections of suitable isolated portions of the fabric deflected by known hydrostatic pressures, the tensions may be determined. The instrument developed at the Bureau of Standards for the Bureau of Aeronautics of the U. S. Navy to measure the stresses in the cover fabric of the airship "Shenandoah," consists of an open chamber having an elliptical cross section and provided with a pressure gage and deflection meter. The construction of the instrument is shown and the theory of its use is given. Around its perimeter is a hollow rim perforated with suction holes, by means of which an elliptical portion of the fabric is isolated.

SATURDAY AFTERNOON AT 2 O'CLOCK

East Building

57. Ionization of HCl. HENRY A. BARTON, Princeton University.—Electromagnetic analysis was employed to determine the value of m/e for ions formed from HCl in the presence of a hot filament from which electrons were accelerated by a known field. Ions were formed having m/e values 1, 2 and approximately 36 and 72, times that of H^+. These were H^+, H_2^+ and ions of one and two Cl atoms respectively, the

latter probably combined with one or more H atoms. Only the hydrogen ions were formed below about .005 mm pressure (impacts of 30 volts) suggesting that the primary process of ionization in HCl results in dissociation rather than formation of $(HCl)^+$ ions. At high pressures (above .02 mm) practically all of the ions were of the two heavier types. This suggests that the H^+ ions are "used up" by attachment to the polar HCl molecules, forming $HCl \cdot H^+$ ions, or perhaps may bind together two molecules, forming $(HCl)_2 \cdot H^+$ ions. Cl atoms or HCl molecules having a negative charge were also observed in large numbers. Experiments are being made to determine the precise composition and origin of all of these ions.

58. The mobility of argon ions in air. HENRY A. ERIKSON, University of Minnesota.—The ions were produced in argon by means of the x-rays from polonium and the argon containing the ions was passed in a thin sheet above a stream of air. By means of an electric field the ions pass from the thin sheet of argon through the stream of air to the plate where the current to a narrow strip is measured for different voltages. It is found that the negative argon ion has the same mobility as the initial positive air ion. It is furthermore found that there is a second positive argon ion which has the same mobility as the final positive air ion. On account of the limited supply of argon it was not possible to determine if the first transforms into the second, as in the case of the air ions. That this takes place is however quite certain. The author believes the first to be a positive argon atom and the second to be a complex formed by the union of the first with a neutral argon atom.

59. Low voltage arc oscillations in nitrogen and in mixtures of hydrogen and nitrogen. C. ECKART, C. T. KWEI and K. T. COMPTON.—With a two electrode discharge tube, consisting of a hot cathode and a nickel plate anode, oscillations were observed at low pressures in nitrogen which set in at or slightly above 17 volts with an amplitude of about two volts in the direction of lower voltage. When hydrogen was mixed with nitrogen with the latter slightly in excess, the oscillations again began to appear at the same voltage. When the maximum voltage dropped below 17 volts due to increase of thermionic current, the oscillations stopped until the plate potential reached 16 volts at which point the tube current increased with a sudden jump (without oscillations). Oscillations came in again when the plate potential was raised to 17 volts, and their maximum reached 20 or 22.5 volts, depending upon the strength of the thermionic current. Oscillations could not be found in pure hydrogen. These results are to be considered as a correction to a paper by Eckart and Compton (Phys. Rev. **24**, 97-122, 1924) who reported failure to find oscillations of this type in hydrogen or nitrogen.

60. Scattering of electrons in ionized gases. IRVING LANGMUIR, General Electric Co.—A homogeneous parallel beam of electrons is produced in ionized mercury vapor at low pressure by accelerating electrons from a hot cathode through a positive ion sheath. Measurements with a plane collector placed normally to the beam prove that with low current densities those electrons which have not collided with atoms move with constant velocity for paths of 6 cm or more. With higher current densities the electrons become scattered having a Maxwellian velocity distribution (temperature T) superimposed on the translational velocity as if the beam of electrons becomes progressively heated as it passes through the ionized gas, without suffering change in average momentum. The effect cannot be due to collisions of the second kind. It is qualitatively like a Compton effect but is more probably caused by accelerations produced by the pulsating fields of excited atoms. The temperature T increases in proportion to the ionization and the length of path; it reaches a maximum at a vapor

pressure of 1 bar and at electron velocities of 50 volts. With 0.03 ampere and 50 volts in vapor at 1 bar, T is about 20,000° when the electron path is 3 cm. Similar effects are observed with hydrogen and with argon.

61. Theory of the magnetron taking into account the variation of mass with velocity. LEIGH PAGE, Yale University.—If the heating current is large, the magnetic field due to this current has an appreciable effect on the critical voltage for cut-off. The exact theory is developed, taking into account both the applied axial field and the concentric field due to the heating current. The exact theory begins to differ from the approximate theory, in which the mass of the electron is treated as constant, by an appreciable amount (2 percent) for a critical potential of 20,000 volts, the divergence being approximately proportional to the potential.

62. Evidence regarding the process of ionization by electron impacts. K. T. COMPTON and C. C. VAN VOORHIS, Princeton University.—Thermodynamical considerations suggest that the primary effect of impacts of electrons against molecules is excitation which may be followed by a secondary process of disintegration (ionization). Smyth and Barton have proved the secondary nature of some such disintegration processes by the method of positive ray analysis. We have obtained further evidence of this process, and also of a contribution to the total ionization due to collisions of the second kind by highly excited molecules. Electrons with controlled speeds were projected into a metal cylinder containing an electrode system of small area for collecting positive ions produced by ionization within the cylinder. A sharp increase in ionization was found at twice the minimum ionizing potential in all gases (A, Ne, He, Hg, N_2, H_2), although the gas pressures were so low as to render negligible any ionization which could be ascribed to those electrons which, after ionizing one atom, might retain their excess energy and ionize another. The observed extra ionization was, in various tests, from 50 to 600 times too large to be attributed to electron impacts under any conceivable conditions. It is explained by ionization at collisions of the second kind between neutral and highly excited molecules.

63. The absorption of hydrogen in potassium vapor arcs. ROGERS D. RUSK, University of Chicago.—Absorption of hydrogen by potassium vapor occurs in the presence of an electric arc, or in the presence of a hot filament, or by heat alone at suitable temperatures. Consideration of the absorption of hydrogen at 300° C due to heat alone indicates the marked tendency of potassium to combine with atomic hydrogen. In the arc, strong absorption is noted at 190° C and at potentials above sixteen volts, due to chemical combination of the potassium and hydrogen. Hence it appears that appreciable dissociation of hydrogen does not occur below sixteen volts. Previously observed traces of absorption below sixteen volts (Phys. Rev. **21,** 720, 1923) are attributed to factors other than chemical action between the hydrogen and potassium. At suitable vapor densities of the potassium, the arc could be maintained as low as six volts. With mercury vapor present in the arc, absorption was noted at voltages below sixteen, due to dissociation of hydrogen by collision with excited mercury atoms.

64. The depolarizing influence of a rapidly changing magnetic field on the resonance radiation. G. BREIT and A. ELLETT, Department of Terrestrial Magnetism, Carnegie Institution of Washington.—It has been shown by Wood and Ellett that the polarization of resonance radiation of mercury which is excited by linearly polarized 2537A radiation becomes practically completely depolarized in suitably oriented steady fields of the order of 2 gauss. We have applied alternating fields of the same magnitude varying the frequency of the alternations, and we have found that the influence of the field becomes

negligible when its frequency is 10^7 cycles per second, while the influence is pronounced at a frequency of 5×10^6 cycles per second. This shows that the life of the excited atom is approximately 10^{-7} seconds. The effect of collisions between atoms has been eliminated by keeping the vapor at a sufficiently low pressure. These experiments furnish a means of finding how rapidly the quantization of an atom responds to the effect of a magnetic field.

65. Ionization of mercury vapor by ultra-violet light. G. F. ROUSE and G. W. GIDDINGS, University of Wisconsin.—In view of recent observations of the ionization of metallic vapors by light, a re-examination of Steubing's early experiment (Phys. Zeits. **10**, 787, 1909) was undertaken. It is found that while the radiation from a hot quartz mercury arc gives no ionization in mercury vapor, that from a similar water cooled arc gives a large ionization current. This indicates that the core of the line λ2536A must be present in the exciting light. A suitable form of tube makes it possible to distinguish between a true ionization current and a possible photo-electric current from the electrodes due to scattered light. Tests made by illuminating with monochromatic radiation show that the line λ2536A alone is not effective, suggesting some sort of a cumulative action. When radiation consisting of lines λ2399A to λ2536A inclusive is refocused in the vapor the ionization effect is obtained. Results are given showing the effect upon the ionization current of gradually narrowing the wave-length range of the exciting light. The mercury vapor in these experiments was at saturation pressures corresponding to temperatures from 150°.C to 200° C.

66. Secondary emission from a nickel surface due to positive ion bombardment. A. L. KLEIN, California Institute of Technology.—An apparatus is used consisting of a number of coaxial nickel cylinders so arranged that they act as grids, shields, collectors, and target. The positive ions were evaporated from hot aluminum phosphate. The target was heated to 1000° C for three minutes before each run. A saturation curve was obtained of the current between the target and the collectors, for each energy of positive ions. This curve is then reduced to the ratio of the secondary current to the primary current. When the collecting voltage becomes high enough to stop reflected positive ions, the curves all show practically horizontal saturation values. Large numbers of positive ions are reflected with velocities between zero and two volts, and there also seems to be a group of reflected positive ions with velocities around nine-tenths of the primary energy for all primary energies used. The saturated secondary electron emission is .35 percent at 50 volts, 1.6 percent at 100 volts, 5 percent at 200 volts, 13 percent at 300 volts, and 22 percent at 380 volts. All runs were made with the target at a temperature approximately 170° C.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program, to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for at any session after the completion of the regular program for the session.

67. Determination of the time of a solar eclipse from measurements of relative illumination. IRWIN G. PRIEST, K. S. GIBSON and F. K. HARRIS, Bureau of Standards.—The objects of this paper is to point out the utility of illumination measurements in determining the time of a solar eclipse. Using the measurements made at the Bureau of Standards at the time of the recent eclipse (see earlier paper by authors in this program) the following data were collected: Magnitude of eclipse (predicted): 0.952. Time of maximum obscuration of sun's disk: as predicted, 9h 4m 27.5s; corrected to accord with observed contacts in totality path (Sci. Am. April 1925, p. 223), 9h 4m 33s; corrected to accord with correction adopted by Naval Observatory on basis of observed first and last contacts at Washington, 9h 4m 33s; corrected to accord with the mean correction for first and last contacts as actually observed by Naval Observatory, Washington, 9h 4m 39s; from illumination data, North Sky (Priest) 9h 4m 35s; direct sun (Gibson) 9h 4m 50s. The present illumination measurements were not intended for this purpose and are much less precise than might have been attained with this end in view. The following are tentative recommendations for future attempts. (1) Illumination to be measured: from whole sky except sun. (2) Methods of photometry: (a) rotatory dispersion (or in lieu of it, blue glass wedges to obtain color match); (b) photographic density. (3) Methods of record: Automatic or semi-automatic record of photometric observations and densities together with time signals by seconds.

68. The isolation of two positive bodies in thorium active deposit. HENRY A. ERIKSON, University of Minnesota.—About 200 gm of thorium nitrate were dissolved in water. A stream of air was passed through the solution and into a large container, carrying with it the thorium emanation. From the container the air and active deposit formed passed in a thin sheet above a stream of air produced by a fan. By means of a field the active deposit ions passed from the thin sheet through the air stream and were deposited on a metal plate. The distribution on this plate was determined by placing it beneath an ionization chamber having a narrow opening in the bottom. When the distance along the plate was plotted against the current a curve having two maxima was obtained similar to that reported earlier in the case of the actinium active deposit. (Phys. Rev. **24,** 622, 1924). There are therefore two positive active bodies in the thorium deposit. In the case of actinium it was suggested that the swifter of the two bodies was an atom of actinium A or B. As it has since been found that atomic argon ions have the same mobility in air as the initial air ion, this suggestion will not hold. It must be concluded therefore that the swifter of the two bodies carries a double charge. This point is under investigation.

69. A mechanism for thermal electron emission. K. H. KINGDON, General Electric Co.—Let there be N atoms per cm^2 of surface, oscillating with the characteristic frequency ν (as used in Einstein's specific heat theory). Further, suppose the amplitudes to be distributed according to Maxwell's law, and the average amplitude to be pro-

portional to $T^{\frac{1}{2}}$. Following Lindemann, take the average amplitude at the melting point T_m to be equal to the distance between atoms, and call this amplitude that necessary for a collision between neighboring atoms. Then the number of collisions per sec. per sq. cm. of surface at temperature T is $a = N\nu[erf(3T_m/2T)^{\frac{1}{2}} + 2\pi^{-\frac{1}{2}}(3T_m/2T)^{\frac{1}{2}}e^{-3T_m/2T}]$. Suppose that transfers of energy take place between electrons in the atoms at collisions, so that an electron is ejected from one of the colliding atoms, and that these electrons have a Maxwell distribution of energy. Then the number of electrons crossing a sq. cm. of the surface per sec. with velocity components normal to the surface between u and $(u+du)$ is $amu/kT)e^{-\frac{1}{2}mu^2/kT}du$, and the number which will escape against the work function ϕ is $ae^{-e\phi/KT}$. Using $\nu = 7.9\times10^{12}$ (from Debye's formula), $N = 1.5\times10^{15}$, $\phi = 4.52$ volts, $T_m = 3655$ for tungsten, the above expression gives emissions within 10 percent of the experimental values over the entire temperature range available.

70. The band spectrum of magnesium hydride. WILLIAM W. WATSON and PHILIP REDNICK, University of Chicago.—The band system of magnesium hydride with principal heads at λλ 5622, 5211, and 4845 has been photographed at high dispersion. P, Q, and R branches of the narrow doublet character are found in which systematic departures from the combination principle appear. The presence of bands attributable to the two less abundant isotopes of magnesium has been established. Both the computed moment of inertia of the molecule and the magnitude of the isotope displacements are in agreement with the hypothesis of a dipole carrier, probably MgH.

71. Observations on the transformation in austenitic steel as induced by cooling in liquid air. HENRY S. RAWDON and FREDERICK SILLERS, JR., Bureau of Standards.—It has been generally assumed in the study of steel that austenitic steel, face centered cubic lattice form, can be readily transformzd into martensite, body centered cubic lattice, by severe cooling (liquid air) by which means the $\nu \rightarrow a$ transformation is caused to take place. The marked 'acicular' structure observed on a previously polished surface of austenitic steel after immersion in liquid air so closely resembles the microstructure of a hardened steel that the conclusion was natural. Observations by the authors by the Hull-Davy method of crystal analysis on an austenitic steel (Ni 26.7 percent, 0.27 percent C) annealed and also after cooling for varying periods in liquid air show that the ν, or face centered cubic lattice, predominates in the material even after severe cooling (75 minutes, .003 to .005'' strip). Some lines indicative of the a, body centered cubic lattice, were found in photographic record of annealed material. These were strengthened by cooling, but on the whole, the ν lattice strongly predominates. Measurements (Fabry and Buisson method) of the relative intensity of the lines showed a gradual decrease in intensity of certain of the ν lines and increase of some a lines. The conclusion that the $\nu \rightarrow a$ change under these conditions is only partial seems to be warranted.